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ABSTRACT

The intent of including history in physics courses is to give young students an increased sense of their own identities and a better understanding of their potential roles in our culture, as well as to show that physics is a valuable activity because it enlarges the variety of human experience. A review of the status of history in secondary school physics deals mainly with a discussion of Project Physics. The need for a larger impact in the area of historical physics is expressed. The lack of teacher preparation in this topic should be overcome by more effort on the part of colleges and in the development of more and better teaching aids. Several source materials are identified. As a summary, four guidelines on teaching the history of physics are proposed: (1) emphasize experimental aspects, (2) avoid the overemphasis of history, (3) use materials relevant to contemporary problems, and (4) investigate the life and time of various physicists. (TS)

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The Use of History in Secondary School Physics *

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The general arguments which support the inclusion of historical materials in any physics course were eloquently set forth in a recent article by Stephen G. Brush.[1] He points out, and rightly so, that the history of science can be a bridge between the sciences and the humanities, and that many students who find it difficult to appreciate the austerity of our traditional courses may be attracted to material with an historical orientation. Brush outlines several ways in which case studies can be woven into the fabric of a physics course, not just for the purpose of making the course more popular with non-scientists, but to add the richness of intellectual history to the traditional "logical" development of the subject matter. In this paper, I would like to offer a particular argument for the inclusion of historical elements in the secondary school physics program based upon an interpretation of our students' intellectual and emotional development. My suggestions for the production of materials designed specifically for use in the secondary school will reflect my understanding of the characteristics of schools, teachers, and pre-service teacher preparation programs that are likely to make the introduction of such materials difficult. Finally, I will propose a set of guidelines for the teacher who wishes to add historical depth and perspective to his course.

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Why history?

Is it realistic to think that students in our high schools are likely to be interested in historical aspects of physics when some of their older brothers and sisters in our college courses are proclaiming that history is irrelevant? It seems to me that we do not always remember that students come into our elective courses with a subconscious wish to learn as much about themselves as they do about physics. They may often possess a veneer of sophistication and apathy, but much of that is due to the fact that they are trapped by an artificially prolonged adolescence in a youth culture which professes to reject old values. It is not a simple task for them to relate to a social order that makes little real demands upon them and gives them few chances to assume significant responsibility. To the extent that our physics courses can serve to give young students an increased sense of their own identities and a better understanding of their potential roles in our culture, we will be more successful as teachers. If we fail to make a contribution to this understanding, even though we think we "cover" the physics, our courses will never achieve their full potential, particularly with those students who do not have any desire to become professional scientists.

It is in this sense that a high school teacher cannot afford to let his students' first experience in physics become merely a preparation for later physics courses, or what is even worse, a barrier that must be hurdled to gain admission to college. It is tempting for a teacher to do so, for the pressure from parents and administrators is liable to be unrelenting. We all know of school districts

whose proudest boast is of the percentage of their students who go on to college, and where the letters from college admissions offices that arrive in the spring are more eagerly awaited than the equinox itself. It is unrealistic to think that we can single-handedly reverse the emphasis, but at least we can strive to make our courses rich and satisfying experiences for students while they are with us; perhaps we should say to our colleagues that it is more important for a student to sense the coming of spring and to marvel at the clockwork motion of the planet than it is for him to complete the syllabus and prepare for the College Board examinations. We must assist our colleagues in the high schools in their task of persuading those who now think otherwise, that high school physics is basically a component of liberal education rather than pre-professional preparation for anything else. The basic objective of any high school science course should be to create an environment in which students can discover for themselves and from the work of others that have preceded them in the quest that there is an underlying world order; that the laws which govern the way things are and the way in which they behave are accessible to the intellect. As teachers of physics, it is the relationship of physical law to human experience and rational processes that we must strive to exhibit, and it is here that history can play a part.

Our students are observant. They may listen to our precepts, but they are more likely to learn from our example. They are quick to sense our attitudes toward the investigation of natural phenomena and the creation of new experience by experimentation. In an environment filled with sensitive antennae, the teacher cannot avoid

becoming an intermediary in all phases of the learning process. His approach to physics will influence his students' conception of the role that physics plays in the larger context of human experience and it is precisely for this reason that an historical approach can be of great value. If we are perceptive, we will understand that a student can profit greatly from an exposure to the philosophy and approach to physics (and life) of more than just his own teacher. A student should be provided with the opportunity to learn how physicists of other times and places have contributed to the evolution of physical theory and man's general understanding of the world. If our introductory course structures are such that the human character of these contributions is deemphasized or obscured, or if we imply that one need only learn the physics and not the context in which the work was done, we only make it difficult for the student to acquire the sense of historical continuity that is basic to the development of mature personality and intellect. A course environment must be created in which the student can learn that the underlying theoretical structures of physics, together with the powerful experimental techniques that are used to test them, are not the work of gods, but of men who may have made mistakes, taken false turns, became discouraged, or perhaps lacked confidence in their results. Appropriately selected glimpses of its rich history can foster an understanding that, in the final analysis, physics is a valuable activity because it enlarges the variety of human experience.

The Status of History of Physics in Secondary School Physics

How do our contemporary high school courses measure up against these

general objectives for liberal education in physics? How is the history of physics utilized to give our students more insights into physics and the drives of those who devote their careers to its study?

The most important recent development in this regard in the U.S. is Harvard Project Physics.[2] For the first time, materials are available as part of a widely publicized physics curriculum project that will enable a teacher to introduce historical materials into the structure of a secondary school physics course. Perhaps "enable" is not the correct word, for the course developers encourage and urge teachers to suggest to students that they may choose historical excursions in the text and in the companion "readers" which contain a great variety of essays related to the basic divisions of the course. The teacher who wishes to do so can choose a blend of readings, laboratories, demonstrations and films to develop an experience in physics that is coherent and accessible to young students. It should be pointed out that the historical materials are not limited to the readings alone, but carry over into the laboratory. Students may perform, for example, a "17th Century Experiment" using an inclined ramp, a steel ball-bearing and water clock to explore the relationship between distance, and time much as Galileo did. Other media complement the text treatment. A documentary film describing the life of Enrico Fermi was prepared for the course in an ambitious attempt to show the remarkable human qualities of the man as well as to present the sweeping breadth of his scientific achievements. It is certainly to be regarded as a major pedagogical contribution of Project Physics, and in the sense of this paper's introduction, would be a valuable

addition to any course that considers 20th century physics. It is clear then, that a teacher who has access to these historical materials is in an excellent position to make them a valuable component of his course, even if he uses another text.

However, Project Physics is still quite new, and has yet to make its full impact upon secondary school physics in the U.S. Although more than 1000 teachers have taken Project Physics training institutes, many more teachers must be trained, materials must be procured, and old patterns must be broken. Those of us who have taught in the secondary schools know how rigid the constraints are, and how difficult it is to introduce innovations. A significant proportion of high school physics teachers are often quite uneasy about matters of physics curriculum reform, because more often than not, they were never trained specifically to teach physics. It is not at all unusual, for example, to find that the physics teacher in a high school may only have completed one general physics course as an undergraduate and he may have to perform yeoman service in the school by teaching other subjects as well. These constraints were well known to the staff that developed Project Physics and led to an attempt to create a course that would appeal to a broad spectrum of teachers and students. Historical materials play an important part in unifying this course, and one can expect that Project Physics will do much for secondary school physics in general.

If we take a close look at physics in most American high schools not yet reached by the thrust of Project Physics, the situation is usually quite different with respect to the utilization of the history

of physics. Despite their excellence, case study approaches of the type prepared by L.E. Klopfer (See Arnold Arons' review of several of Klopfer's case studies of physics that appeared in Phys. Teach. 6 184 (1968)) do not seem to be widely used in U.S. schools. Many of the teachers that one meets believe that historical approaches have little place in a physics course because of the need to race through the syllabus. Some think that history is flatly inappropriate. Still others are quick to point out that many widely used standardized examinations do not yet make any allowance for historical options by including appropriate examination questions. New York State is a prime example. I think that one can make the flat generalization that unless the Regents examination in physics includes such options, most teachers in the state will shy away from the history of physics in their courses.

Of course there are exceptional teachers. They have long recognized that an historical approach, or the existence of historical or philosophical options within their basic course structures can lend harmony and coherence to their students' conception of physics. In the hands of these skilled men and women, such an approach turns out to be successful even when the so-called historical option is understood not to be historical research in anything approximating the formal notion, but rather the type of invitation to inquiry that encourages the student to penetrate more deeply into the evolution of physics by reading an occasional "first paper" or other source. These are the teachers to whom we must turn for leadership and counsel if we are to make any headway in encouraging the use of historical materials.

Teacher Training and Texts

It would be relatively simple if we could just place the blame upon our teachers and a materialistic society that has little time for history, or lay it at the door of those who are responsible for determining the structure of standardized examinations. Unfortunately, it is clear that a substantial part of the problem rests with college and university physics departments that, at least in the past, have made little attempt to contemplate historical matters in their own courses. One wonders, for example, if many physics departments make joint faculty appointments with history or philosophy departments. One wonders even more whether enough of our physics' departments took seriously the recommendation of the Commission on College Physics Panel on the Preparation Of Teachers[3] when it suggested that a course in the philosophy and history of physics should be a vital element in the preparation of physics teachers, or that physics students preparing to teach in secondary schools should become familiar with some classic original research papers, especially from 19th century sources.

In fairness, it should be pointed out that many authors of physics texts have made an attempt to describe collateral readings appropriate both for teachers and students. The PSSC text, for example, makes extensive reference to a variety of resources. These suggestions are sufficient for the teacher with a strong preparation who has enough confidence in his mastery of the subject to take the excursion with his students. However, when teachers with marginal preparations in physics are asked to use such resource materials, they are often reluctant to become involved in a situation from which they may not be able to extricate themselves gracefully. It is one thing to guide students through a

text that channels student questions through definite routes, asks many questions explicitly, and which is accompanied by a guide that has extensive discussions of key portions of the material; it is something else again to clear a path through unexplored country. Our exceptional teachers set forth on such intellectual ventures routinely and thrive upon the diet, but it is unrealistic to think that a teacher with one or two college physics courses behind him can operate regularly in this mode.

Needed Teaching Aids

If original source materials or other readings are to be used extensively by marginally prepared teachers of physics, it is probably essential that a running commentary or guide be prepared to accompany them. There are some precedents for this. Morris Shamos' Great Experiments in Physics,[4] for example, utilizes extensive introductions and annotations to guide the reader. The Klopfer series referred to earlier is also well-designed in this respect. One wishes that more editors were as thoughtful as the group led by Emilio Segre when they assembled the material to complete the Collected Papers of Enrico Fermi.[5] In addition to a magnificent biographical introduction, the value of each group of original papers is enhanced because it is prefaced by a lucid editorial introduction which describes the origins and significance of the series. Segre, for example, wrote a 4000 word introduction to a series of papers describing Fermi's work with slow neutrons that could stand on its own as an excellent tutorial. These essays, and some of the original papers could be assigned as supplementary reading

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so that students could learn for themselves that concepts which appear colorless in a text were developed laboriously, and involved an interplay between theory and experiment.

Other teachers may wish to utilize readings that are not to be considered as original source materials, but which were written by the person who did the original work. A prime example of this type would be Nobel Lectures in Physics,[6] a magnificent 3 volume set. These can often be used to good effect in conjunction with or as a substitute for the original paper which might be too difficult for a high school student to handle.

It might be desirable to combine these notions by creating resource packets of the type suggested some years ago by H.R. Crane, and popularized more recently by the Commission on College Physics when it assembled a group of 2 and 4 year college teachers to create resource packets treating contemporary themes in physics and designed to assist a modestly prepared 2 year college teacher in the preparation of an illustrated lecture. The same kind of packet with an historical theme or emphasis could be assembled for the use of high school teachers and students who are not likely to have access to an extensive library collection. Such a packet might include an original paper, a commentary describing the significance of the work, preferably written by the original author, a modern discussion of the same topic (say a Scientific American offprint), copies of newspaper accounts of the research if it was sufficiently newsworthy at the time to attract the attention of the press, and suggestions for related laboratory work that could be realistically attempted in the high school, complete with lists of apparatus and references. It would also be useful to include a brief biography of the original researcher, suggestions for further reading, and a list of sources of related

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films or other audio-visual aids. The packet would be completed by the inclusion of a detailed description of the way in which the materials could be used in classroom situations, including sample examinations or essay topics. The matter of examination questions is quite critical, for many teachers who have reservations about the use of historical materials in physics courses are likely to remember questions of the "who did what" variety with understandable distaste. They will have to be convinced that it is possible to develop evaluation schemes that measure understanding before they will consider course options involving the history of physics.

Guidelines

How are the materials to be used? What guiding principles should be proposed to teachers who would like to try to introduce these materials into their courses? I would like to suggest four that I think would be useful.

First, it would seem wise to concentrate on the experimental aspects of physics. Shamos' book, Great Experiments in Physics is an outstanding work, and could serve as a model for a smaller collection of readings appropriately chosen for high school students. We all know too many students, in high school and college, who possess a glib facility with words and can rattle off all kinds of statements about physics, but who become suddenly inarticulate when they are asked to explain the experimental foundations of the concepts. If one wishes to talk intelligently about neutrons , for example, one should be able to explain how we know that neutrons exist in the nucleus, how we are able to detect free neutrons,

and how one might go about measuring some of the neutron's various properties. I propose that, in general, things should not be discussed at length in high school physics courses unless students are able to understand the supporting experimental evidence. This need not always be done quantitatively; if a high school student can describe Chadwick's experiment in qualitative terms, he can rightfully claim some measure of true understanding.

Some may protest that this criterion would sharply limit the kinds of things which one could talk about in a high school course, but that is precisely the point. Too many of our high school courses can best be described as crowded--not with students, unfortunately, but with too much physics. Because of this, we drive away or keep out many students who just cannot keep up with the pace. We must always keep in mind the crazy-quilt character of the average high school day, with students taking 4 or 5 academic subjects daily, with 5 minute intervals between classes. What this does to the quality of life in the schools, both for students and teachers, would be a good subject for another essay.

That brings me to the second guideline. A teacher should avoid the temptation of assigning <u>too much</u> history of physics, even to the student who expresses an interest. Most of us enjoy meeting young persons who are interested in our subject; some of us have a tendency to give too much extra work to them, with the end result that they decide to keep quiet or stay away. We all know the student who finishes one mathematics course splendidly and is given two Advanced Placement courses the next time around. Physics teachers in the schools must be assured that their college and university colleagues are not going to expect entering freshmen with one physics course behind them to have

an extensive command of the history of physics. I would suggest that one or two historical projects, during the high school physics course would be more than sufficient to accomplish some of the objectives discussed earlier.

The third guideline has to do with the desirability of using historical materials that are relatively contemporary. There are topics in physics that have great appeal to students because they can talk to others about them outside of class. Radioactivity, for example, is a rich subject for high school investigation because of the wealth of historical biographical, and experimental material that is available. Students are very much interested in areas such as this because they can discuss them with their peers and parents and really know what they are talking about. It is always good experience for a student to be a local authority on something; in addition to the place of this kind of investigation in liberal education, such activities often lead to a student's first glimpse of the fact that one could build a career around this kind of work, and give him the confidence he needs to go further.

The fourth and final guideline deals with the desirability of encouraging students to investigate the life and times of a physicist as well as his work. Consider Niels Bohr, for example. His early work, alone, would provide a lifetime of work for the professional historian. Various parts of the 1913 paper could undoubtedly be read by high school students to supplement the text development of his atomic model. I would propose that an alternative might be appropriate for many students who are not really interested enough in physics to pursue that line of investigation. Some of them might be considerably more interested in Bohr as a scientific statesman. Such students could read S. Rozental's

collection of essays, Niels Bohr- His Life and Work as seen by his friends and colleagues [7] and explore some of the facets of Bohr's life that are not widely known to non-physicists. Many of the essays do not dwell upon the work as much as upon the man and the way he looked at the world. Readers would learn that the vitality, compassion, and sense of human dignity engendered in Bohr as a child characterized his entire life, first in relationships with his own family and colleagues, and later in the extension of his concern to the problems of a modern society seeking to control weapons which, for the first time in history, seemed capable of producing worldwide disaster.

Other students might be interested in the life of Robert Oppenheimer. Here, too, there is a wealth of material that could be used. Biographies, dramas, and accounts from many points of view all combine to provide the student with a rich lode of source material to be explored in the process of learning about a man whose life became inextricably entwined in 20th century physics and politics.

Some may feel that such topics have no place in high school physics, but it seems to me that an interpretation of the role of the high school in which the physics course is seen primarily as pre-professional cannot stand up under close scrutiny. It is precisely this interpretation that has limited the number of students enrolling in high school courses by making teachers feel that problem solving is the sine qua non of success. I happen to agree that Lord Kelvin's well-known dictum, "When you can measure what you are speaking about and express it in numbers, you know something about it," is appropriate for physicists, but I envision the high school physics course as a place where students and teachers need to be given the utmost latitude in deciding what is to be studied and

and how it is to be pursued. Historical options can play an important part in such a course and I would encourage teachers to give their students free rein.

Support From The Profession

One should be careful, however, not to be overly optimistic. The creation of resource packets, the wide availability and influence of Project Physics materials and pontifical exhortations in the name of humanism will all have little impact unless more college and university physics departments, AAPT, and the various councils and committees of our societies and institutes use their prestige and influence to change the existing pattern of pre-service teacher training in the direction suggested by the Commission on College Physics. Only then will our students who are potential high school teachers accept the sincerity of our suggestions regarding the inclusion of the history of physics in our high school courses. If we talk of historical perspective while confronting them with endless sets of problems, they will know whose side we are on. At the same time we must work closely with those responsible for the College Board Achievement Test and other examinations which are carefully watched by teachers of physics to ensure that appropriate test options are developed. If we do not do at least this much, we cannot expect to be taken seriously.

In summary, I have suggested that our young persons need to be given the opportunity to learn for themselves that physics is an activity with a rich history, and that its ultimate contribution to society, in addition to the technologies which derive from it, consists in its expansion of human experience. Historical elements in physics courses

can be designed so that they add coherence to our students' understanding of physical law and its evolution. New courses now exist which may be sufficient to provide a critical mass of materials, but much work must be done before we can persuade sorely pressed teachers to consider modifying their traditional programs.

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